Article

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Abstract: Computer-aided design/computer-aided manufacturing (CAD-CAM) technology is growing in significance for prosthodontic treatment due to its impact on clinical performance and patient outcomes. It has been integrated into dental education to allow students to experience digital workflows. Despite these advancements, many dental students still lack sufficient knowledge of CAD-CAM technologies. A cross-sectional survey was conducted at the College of Dentistry, Imam Abdulrahman Bin Faisal University. Based on previous studies, a validated questionnaire was distributed to undergraduate dental students and interns. The questionnaire assessed their knowledge and attitudes toward CAD-CAM technology in prosthetic dentistry. The responses were analyzed using descriptive statistics, and a chi-square test was used to study the association between knowledge and practice and the study year level. A total of 170 students participated in the study, with a mean age of 22.2 (±2.5) years. The proportion of female participants was 65.9%, and 34.1% for males. Knowledge varied across academic levels, with 4th- and 5th-year students demonstrating greater theoretical knowledge, while 6th-year students and interns showed more practical experience. Only three of the 18 knowledge-related questions received a correct response rate above 70%. Most participants (86%) reported acquiring knowledge from undergraduate courses, and 88% expressed interest in further training. CAD-CAM technology was most commonly practiced for fixed prostheses, and intraoral scanning was the most frequently used digital workflow. The study highlights the need to improve CAD-CAM education. While lower-level students displayed solid theoretical knowledge, advanced students benefitted from more practical exposure. Increasing hands-on experience and access to digital equipment is essential for preparing students to meet the demands of modern digitalized dentistry.

Keywords: CAD-CAM; dental education; dental practice; digital curriculum; intraoral scanner; knowledge

1. Introduction

It is essential to provide suitable education on computer-aided design/computer-aided manufacturing (CAD-CAM) technology due to its growing significance in prosthodontic treatment.

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Some dental schools have incorporated this CAD-CAM into dental students' education as a new concept. [1] This incorporation enables students in preclinical programs to evaluate the differences between conventional and digital impressions, as well as experience restoration fabrication utilizing a digital workflow [1,2].

Integrating CAD-CAM technology in dentistry has significantly enhanced clinical performance and patient care quality [12,13]. By automating the design and fabrication of dental restorations, CAD-CAM systems have greatly improved dental prostheses' precision, efficiency, and aesthetic quality [12]. The digital workflow facilitates data acquisition through intraoral scanners, reducing the need for traditional impressions and shortening the turnaround time for restorations [13]. Further, materials such as zirconia, resin composites, and ceramic blocks used in CAD-CAM systems offer superior mechanical properties, enhancing the durability and functionality of restorations [12,13]. These materials have demonstrated consistent clinical performance in both prosthetic and restorative applications, contributing to long-term stability and comfort for patients [12]. Moreover, CAD-CAM-produced restorations exhibit excellent biocompatibility, strength, and esthetics, making them a highly favorable option in modern dentistry [12,13].

With the widespread use of CAD-CAM technology, it should be incorporated into undergraduate courses, including preclinical and clinical, allowing students to practice and gain the necessary knowledge for its application in clinical settings. By recognizing the value of this technology, students will be more likely to adopt it in everyday practice in their future clinical work [9]. This survey aims to detect the level of awareness among undergraduate students about the application of CAD-CAM technology in prosthodontics.

2. Materials and Methods

The participants were informed about the aims of this study, and their consent for participation was obtained. The study was conducted at the College of Dentistry, Imam Abdulrahman Bin Faisal University, after IRB approval (IRB-2022-02-229). Undergraduate dental students and interns at the College of Dentistry, IAU, were included in this study.

A validated questionnaire was prepared based on previous studies [8,10,11]. The questionnaire covered all necessary information regarding three categories: intraoral scanner for digital impression, complete denture fabrication by subtractive method (milled denture), and additive method (3D-printed denture). It included information regarding the machines, materials, and various techniques used in the digital workflow and fabrication of removable prostheses. All participants completed the questionnaire, which was specifically designed for this study. The questionnaire consisted of two sections. The first section gathered general participant data (age, gender, and level of education). The second section included 24 questions designed to evaluate students' attitudes toward CAD-CAM technology in prosthetic dentistry.

For validation, additional steps were taken by randomly selecting students and prosthodontic faculty members to review the questionnaire. Based on the feedback from the randomly selected sample and faculty responses, the questionnaire was revised and modified accordingly. After questionnaire modification and validation procedures, the questionnaire was distributed physically by a research team to the attended students of each class level in a classroom and re-collected once they completed the questionnaire.

The collected data consisted of three sections. The first section consisted of the participants' demographics, the second section was about knowledge and awareness about CAD-CAM, and the last was about the practice. The responses to the knowledge section questions were collected as "yes, no, and not sure." However, after the completion of data collection, the correct answer for each question was coded as "good", and the remaining responses were marked as "poor". Hence, the responses to each knowledge question were transformed as "good or poor".

The statistical analysis software used in the study was Statistical Package for Social Sciences (SPSS v.23, IBM Corp., New York, NY, USA). In the descriptive analysis of the data, means, standard deviations, frequency, percentages, and bar diagrams were used. For the inferential data analysis, the chi-square test was used to study the association between knowledge and practice questions with the

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study year level of the participants. All p-values less than 0.05 were considered statistically significant.

3. Results

The response rate was 100% as the questionnaire was collected immediately after the completion of all invited participants. A total of 170 dental students were included in this study, with a mean age of 22.2 (±2.5) years. The proportion of female participants was higher than male participants, with 112 females (65.9%) and 58 males (34.1%). In terms of academic year levels, Figure 1 illustrates the distribution of participants across the different academic years.

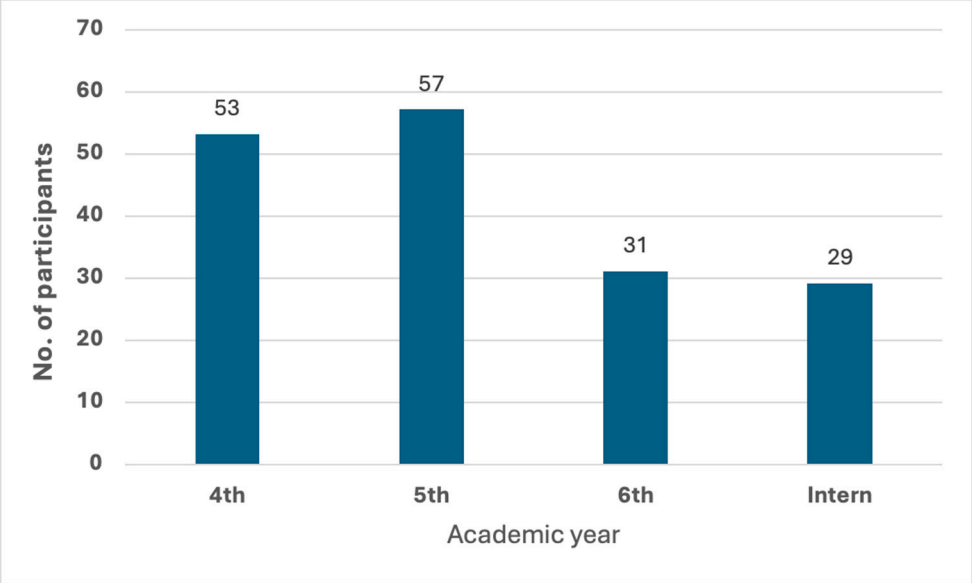

Figure 1. Number of participants.

Among the 18 knowledge-related questions, only three achieved a correct response rate of 70% or higher. The lowest correct response was observed for question 4, with only 25 participants (14.8%) out of 170 answering it correctly (Table 1).

Table 1. Practice of knowledge responses.

Knowledge	Good No. (%)	Poor No. (%)
Q1: Is digital intraoral impression required for CAD-CAM fabrication of dental restorations?	89(52.4)	81(47.6)
Q2: Is digital impression recommended for all prosthodontics situations without any limitations?	115(67.6)	55(32.4)
Q3: Is intraoral used exclusively to scan tissues intraorally?	67(39.4)	103(60.6)
Q4: Does intraoral scanning produce more accurate digital casts than lab scanner?	25(14.8)	144(85.2)
Q5: Is the use of intraoral scanners easier than lab scanners?	58(34.1)	112(65.9)
Q6: Are the steps for intraoral scanning used to produce fixed and removable prostheses the same?	54(32)	115(68)
Q7: Can complete dentures be made/fabricated using CAD-CAM technology in two visits?	78(45.9)	92(54.1)
Q8: Is CAD-CAM technology more precise than conventional techniques for the same dental procedure?	115(67.6)	55(32.4)

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Q9: Does CAD-CAM technology produce faster restoration than conventional methods?	144(85.7)	24(14.3)
Q10: Can three-dimensional (3D) printing technique be used for complete denture fabrication?	119(70)	51(30)
Q11: Are milled and 3D-printed technologies same for scanning denture fabrication?	63(37.1)	107(62.9)
Q12: Are milled and 3D-printed technologies same for designing denture fabrication?	65(38.2)	105(61.8)
Q13: Are milled and 3D-printed technologies same for production denture fabrication?	53(31.2)	117(68.8)
Q14: Are denture base materials used for milling and 3D-printed technologies the same?	63(37.5)	105(62.5)
Q15: Are there differences in the mechanical properties of the PMMA used for conventional heat-polymerized, CAD-CAM milled or 3D-printed removable dentures?	72(42.4)	98(57.6)
Q16: Can removable partial dentures be digitally designed?	120(71.4)	48(28.6)
Q17: Can removable partial denture be fabricated using subtractive technology?	81(47.6)	89(52.4)

Table 2 presents the comparison between year-level and knowledge-related questions. It was observed that 4th- and 5th-year students had a higher rate of correct responses for 8 out of 18 questions. In contrast, for the remaining ten questions, 6th-year students and interns had a higher rate of correct responses. Additionally, statistical significance was identified in questions 3, 5, and 11. For question 3, a significantly higher proportion (49.1%) of 5th-year students answered the correct answer compared to students of other year levels (p=0.044). For question 5, 6th-year students had a significantly higher proportion (54.8%) of correct responses compared to other year levels. Furthermore, in question 11, 57.9% of 5th-year students answered it correctly, with their proportion being significantly higher than that of other year levels (p=0.001).

Table 2. Comparison of knowledge with study year level.

Questions	Responses	Year level				P-value
		4th	5th	6th	Intern	
Q1	Good	34(64.2)	29(50.9)	11(35.5)	15(51.7)	0.088
	Poor	19(35.8)	28(49.1)	20(64.5)	14(48.3)	
Q2	Good	33(62.3)	39(68.4)	21(67.7)	22(75.9)	0.657
	Poor	20(37.7)	18(31.6)	10(32.3)	7(24.1)	
Q3	Good	23(43.4)	28(49.1)	6(19.4)	10(34.5)	0.044*
	Poor	30(56.6)	29(50.9)	25(80.6)	19(65.5)	
Q4	Good	7(13.2)	7(12.5)	5(16.1)	6(20.7)	0.757
	Poor	46(86.8)	49(87.5)	26(83.9)	23(79.3)	
Q5	Good	10(18.9)	21(36.8)	17(54.8)	10(34.5)	0.009*
	Poor	43(81.1)	36(63.2)	14(45.2)	19(65.5)	
Q6	Good	16(30.8)	17(29.8)	11(35.5)	10(34.5)	0.937
	Poor	36(69.2)	40(70.2)	20(64.5)	19(65.5)	
Q7	Good	23(43.4)	28(49.1)	18(58.1)	9(31)	0.187
	Poor	30(56.6)	29(50.9)	13(41.9)	20(69)	
Q8	Good	33(62.3)	42(73.7)	19(61.3)	21(72.4)	0.471
	Poor	20(37.7)	15(26.3)	12(38.7)	8(27.6)	
Q9	Good	45(88.2)	45(78.9)	29(93.5)	25(86.2)	0.266
	Poor	6(11.8)	12(21.1)	2(6.5)	4(13.8)	
Q10	Good	33(62.3)	41(71.9)	29(83.9)	19(65.5)	0.193
	Poor	20(37.7)	16(28.1)	5(16.1)	10(34.5)	
Q11	Good	13(24.5)	33(57.9)	9(29)	8(27.6)	0.001*

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	Poor	40(75.5)	24(42.1)	22(71)	21(72.4)	
Q12	Good	20(37.7)	28(49.1)	9(29)	8(27.6)	0.147
	Poor	33(62.3)	29(50.9)	22(71)	21(72.4)	
Q13	Good	12(22.6)	23(40.4)	12(38.7)	6(20.7)	0.096
	Poor	41(77.4)	34(59.6)	19(61.3)	23(79.3)	
Q14	Good	21(40.4)	21(37.5)	14(45.2)	7(24.1)	0.366
	Poor	31(59.6)	35(62.5)	17(54.8)	22(75.9)	
Q15	Good	25(47.2)	24(42.1)	14(45.2)	9(31)	0.546
	Poor	28(52.8)	33(57.9)	17(54.8)	20(69)	
Q16	Good	33(63.5)	43(75.4)	24(80)	20(69)	0.357
	Poor	19(36.5)	14(24.6)	6(20)	9(31)	
Q17	Good	27(50.9)	27(47.4)	13(41.9)	14(48.3)	0.887
	Poor	26(49.1)	30(52.6)	18(58.1)	15(51.7)	
Q18	Good	29(55.8)	38(66.7)	21(67.7)	14(48.3)	0.275
	Poor	23(44.2)	19(33.3)	10(32.2)	15(51.7)	

* indicates a level of significance.

Table 3 summarizes the CAD-CAM practice among all participants. A total of 86% of participants reported acquiring information from undergraduate courses, with 58% gaining it theoretically, while 41% received both theoretical knowledge and hands-on experience. The majority of participants (70%) indicated that CAD-CAM teaching and training were beneficial, and 88% expressed interest in further training on CAD-CAM practices. Meanwhile, 79% of participants had not attended any extracurricular training.

Table 3. Distribution of practice responses.

Questions	Responses	No.(%)
Q5: Were you taught about the different uses of CAD-CAM technology in your undergraduate courses?	Yes	146(86.4)
	No	23(13.6)
Q5a: If yes, what type of teaching/training was provided?	Theoretical only	89(58.9)
	Theoretical and hands-on training	62(41.1)
Q5b: Was teaching/training useful?	Yes	109(70.8)
	No	45(29.2)
Q6: Are you interested in learning more about CAD-CAM?	Yes	149(88.2)
	No	20(11.8)
Q7: Did you attend any extracurricular education courses dedicated for CAD-CAM training?	Yes	34(20.2)
	No	134(79.8)
Q8: Did you work with CAD-CAM technology before in your practice?	Yes	47(28)
	No	121(72)
Q8a: Which element of CAD-CAM technology did you work with?	Fixed dental prostheses	50(58.1)
	Removable dental prostheses	11(12.8)
	Oral appliances	17(19.8)
	Occlusal devices	7(8.1)
	Pediatric (space maintainer)	1(1.1)
Q8b: Which element of CAD-CAM technology did you work with?	Digital intra-oral impressions	65(54.2)
	Laboratory scanning of models and impressions	23(19.2)
	Performing CAD	22(18.3)
	Performing CAM	10(8.3)
Q8c: If no, what was the reason for not using CAD-CAM?	Non-availability of CAD-CAM	64(39.2)
	Non-accessibility to CAD-CAM	7(4.3)
	Inferior quality of restorations	35(21.5)

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	I am not very technologically aware	44(27.0)
	No advantages of CAD-CAM	3(1.8)
	Other	10(6.1)
Q8d: How many fixed dental CAD-CAM prostheses did you fabricate during the last year?	None	133(80.1)
	1-2	24(14.5)
	3-5	6(3.6)
	6-10	2(1.2)
	More than 10	1(0.6)
Q8d How many removable dental CAD-CAM prostheses did you fabricate during the last year?	None	150(90.4)
	1-2	11(6.6)
	3-5	4(2.4)
	6-10	1(0.6)
	More than 10	0
Q9: What materials do you regularly use with CAD-CAM?	Strengthened ceramics	32(16.4)
	Composite	8(4.1)
	Metals	8(4.1)
	Polycrystalline ceramics	22(11.3)
	I do not use CAD-CAM	91(46.7)
	I do not know	34(17.5)
Q10: Within the CAD-CAM work-flow, which elements do you feel need improvement in order to facilitate and streamline your work?	Intra or extra oral scanning	46(23.3)
	Cad design on computer	30(15.2)
	CAM manufacture of prostheses	23(11.6)
	I do not know	98(49.7)
Q11: Do you think it is important to implement CAD-CAM technology in dental practice?	Yes for all specialties	83(49.7)
	Yes for some specialties	71(42.7)
	Yes for dental restorations only	4(2.4)
	No	9(5.4)
Q12: Do you plan to use CAD-CAM technology in the future?	Yes	156(93.4)
	No	11(6.6)
Q13: Which of the following materials can be used in CAD-CAM technology for denture base fabrication?	Metal	71(17.1)
	Zirconium	69(16.7)
	Light polymerized acrylic resin	88(21.3)
	PMMA	33(8.0)
	Wax	103(24.9)
	Fluid resin	50(12.1)

A small percentage of participants reported practicing CAD-CAM, with the highest frequency of use for fixed dental prostheses compared to removable prostheses and other dental devices. Intraoral digital impressions were the most commonly practiced element of the digital workflow, with 54% of participants. Among those utilizing CAD-CAM in clinics, the average of two completed cases, with fixed dental prostheses being more prevalent than removable ones.

There was an equal distribution of responses regarding CAD-CAM technologies, materials, and digital workflows, though many participants selected the "I don't know" response. However, most participants suggested the incorporation of CAD-CAM technology into all dental specialties and advocated for additional courses and hands-on training following their initial exposure to CAD-CAM.

The comparison between study year levels and the practice-related questions is summarized in Table 4. In response to question 5a, a significantly higher proportion of 6th-year students reported receiving theoretical education or training ($p<0.001$). Additionally, when students were asked about the usefulness of the education or training (Q5b), a significantly higher proportion of 6th-year students disagreed, stating that it was not useful ($p=0.000$). When asked about previous use of CAD-CAM

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technology, 69% of interns responded affirmatively, which was significantly higher compared to other year levels (p=0.000) (Table 4).

Table 4. Practice responses in comparison with the study year level.

Questions	Responses	Year level				P-value
		4th	5th	6th	Intern	
Q5	Yes	41(77.4)	51(91.1)	26(83.9)	28(96.6)	0.051
	No	12(22.6)	5(8.9)	5(16.1)	1(3.4)	
Q5a	Theoretical only	15(34.9)	39(75)	24(88.9)	11(37.9)	0.000*
	Theoretical and hands-on training	28(65.1)	13(25)	3(11.1)	18(62.1)	
Q5b	Yes	37(84.1)	36(66.7)	11(40.7)	25(86.2)	0.000*
	No	7(15.9)	18(33.3)	16(59.3)	4(13.8)	
Q6	Yes	48(90.6)	47(83.9)	29(93.5)	25(86.2)	0.527
	No	5(9.4)	9(16.1)	2(6.5)	4(13.8)	
Q7	Yes	9(17)	14(25.5)	4(12.9)	7(24.1)	0.461
	No	44(83)	41(74.5)	27(87.1)	22(75.9)	
Q8	Yes	12(22.6)	11(20)	4(12.9)	20(69)	0.000*
	No	41(77.4)	44(80)	27(87.1)	9(31)	
Q12	Yes	47(90.4)	51(92.7)	30(96.8)	28(96.6)	0.604
	No	5(9.6)	4(7.3)	1(3.2)	1(3.4)	

* indicates a level of significance.

4. Discussion

CAD-CAM technology has increasingly permeated across all specialties of the dental field, offering high-quality, digitally fabricated prostheses with clinically acceptable performance [2,8,10]. Accordingly, assessing the level of awareness and practical engagement of CAD-CAM technology among undergraduate students is crucial [14,15]. The findings of this questionnaire-based study indicate significant variations in both awareness and practice of CAD-CAM and digital dentistry across different student levels. While it was expected that higher-level students would possess greater knowledge and practical experience, the results reveal that 4th- and 5th-year students exhibited a higher level of knowledge compared to their senior counterparts. However, practical experience was more prevalent among students at the advanced levels.

The higher knowledge observed in lower-level students may be attributed to their ability to effectively memorize the recently acquired information in updated courses that incorporate more digital dentistry implementations. In agreement with a previous study [10], it was reported that "Although undergraduate knowledge of CAD-CAM technology has improved, further education on its clinical applications is crucial to ensure students are fully prepared for the evolving field of digital dentistry [3,8,15]. In earlier years, due to the emergence of new systems and devices, higher-level students exhibited lower knowledge compared to those enrolled in the last three years. The widespread adoption of digital dentistry, driven by increasing competition among companies, the variety of systems available, and the greater accessibility of information, has provided an opportunity to acquire more knowledge that has since been integrated into the curriculum as a core component of CAD-CAM technologies. A previous study [5] investigated the knowledge of students about CAD-CAM technologies related to levels and found that students at lower levels exhibited greater theoretical knowledge due to the recent incorporation of updated digital dentistry content into their courses, while higher-level students had more practical experience with CAD-CAM technologies [8]. This distinction reflects the curriculum structure, where lower-level students are exposed to foundational concepts, whereas higher-level students gain hands-on experience in clinical settings. However, despite their practical exposure, the study noted that higher-level students still lacked up-to-date theoretical knowledge, likely due to the rapid advancements in digital technologies and the evolving nature of the field. This gap highlights the importance of continuously updating the

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curriculum's theoretical and practical components to ensure students are fully equipped for digital dentistry [8].

Most participants demonstrated limited knowledge of the technologies related to various digitally fabricated prostheses, particularly regarding the digital workflow and production technology. There were also noted gaps in understanding the differences between devices used in the digital workflow, such as different scanners and their applications [8,11]. This highlights the need for more emphasis on the digital workflow, from scanning to fabrication, tailored to each dental specialty. A previous study [10] investigated students' knowledge of CAD-CAM technologies and found that, while awareness had improved, gaps remained in their understanding of practical clinical applications, highlighting the need for enhanced training to better equip future dentists for digital dentistry.

The majority of participants demonstrated a good level of practical experience. Most reported receiving information and motivation to practice CAD-CAM through the curriculum, continuous education at the undergraduate level, and participation in various workshops [20]. This highlights the importance of implementing CAD-CAM training and, accordingly, course requirements for digitally fabricated cases [16,17]. Besides, the higher levels of practical experience seen among students can be attributed to their exposure to a broader range of clinical cases as well as their use of digital labs [18]. This is in agreement with studies that emphasize the positive impact of practical experience and clinical exposure on skill development, which reported that practical learning environments accelerate the application of CAD-CAM technology in clinical settings, leading to improved competence among students [10]. However, in disagreement with previous studies, which suggested that the theoretical knowledge gained from lectures alone was sufficient for students to develop CAD-CAM skills, underestimating the importance of direct clinical experience and digital lab work. The results of this study underscore the need for a balanced approach that combines both theoretical knowledge and practical exposure to fully prepare students for the demands of digital dentistry [15].

Most participants utilized CAD-CAM technology to fabricate various prostheses, particularly fixed ones. However, the number of digitally treated cases per participant was relatively low, likely due to the limited availability of digital equipment. Those who used CAD-CAM for prosthesis fabrication reported positive feedback, higher satisfaction, and more straightforward treatment procedures than conventional methods [13,23]. Participants also noted high levels of patient satisfaction, attributing this to the efficiency of the digital workflow and the clinical outcomes of digitally fabricated prostheses [19]. Bhaskar et al. concluded that students who are aware of digital denture systems, such as CAD-CAM dentures, reduce both clinical chair time and the number of patient visits [20].

In our study, 54% of participants identified intraoral digital impressions as the most prevalent element of the digital workflow, and using CAD-CAM technology for creating fixed dental prostheses garnered the highest response rate at 58.1%. This preference may stem from the accessibility and simplicity of the systems and machines designed for fabricating fixed prostheses, often considered superior to removable options. Research by Ishida et al. aimed at assessing the integration of CAD-CAM technology in creating complete and partial dentures among dental students in the US revealed that CAD-CAM complete dentures are included in the curriculum for 54.2% of undergraduates and 65.2% of postgraduate residents [24]. In contrast, CAD-CAM removable partial dentures are covered in only 37.5% of undergraduate courses and 47.8% of postgraduate curricula, likely due to constraints such as limited funding, resources, time, and faculty availability for teaching CAD-CAM in removable prosthodontics [24].

The drawbacks of additively manufactured prosthetic materials and technologies, including expensive equipment and materials, limited material options, technological limitations, complex design, and lack of practical experience, present obstacles to using CAD-CAM in prosthetics. Addressing these limitations can significantly improve the efficiency, accuracy, and outcomes of prosthetic CAD-CAM applications. Likewise, advancements in material science and post-processing methods can significantly enhance the quality, precision, and durability of additively fabricated

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prostheses, making them more reliable and accessible [9,14,18]. Two technologies are used for prosthesis fabrications: subtractive technologies and additive technologies [21–23]. Participants practiced both technologies, though with a limited selection of materials. They used milled ceramic materials for fixed prosthesis fabrication, while other materials such as titanium, titanium alloys, and chrome cobalt alloys they didn't use. This may be due to the lack of a system for these materials or the machine used for fabrications [12,22]. By addressing these gaps, the implementation of CAD-CAM technology in dental education can be more effective, ensuring students are prepared for clinical practice in an increasingly digitalized field of dentistry.

With the widespread adoption of digital dentistry, there is a growing demand for updated knowledge and practical experience across different educational levels. According to the findings of this study, while digital dentistry has been incorporated into prosthodontic courses at various undergraduate levels, there remains a need for further updates and integration of new materials. Besides, the positive feedback from participants practicing and treating patients using digital methods emphasizes the clinical significance of this study. However, more facilities were recommended to enhance hands-on practice and clinical outcomes.

The present study provides important information regarding dental students' knowledge and skills in digital dentistry. However, the results cannot be generalized due to the relatively small number of participants and the inclusion of students from a single college of dentistry. Future studies involving a larger number of participants from various colleges of dentistry are needed to allow comparison and generalization of the study results.

5. Conclusions

Dental students possess a good understanding of digital dentistry in prosthodontics, with lower-level students demonstrating a higher theoretical knowledge while higher-level students exhibited good practical skills. However, there is a need to further emphasize the digital workflow of prosthesis fabrication, from scanning and designing to the final fabrication process, as a core component of the curriculum for undergraduate students at all levels.

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References

1. Callan RS, Blalock JS, Cooper JR, Coleman JF, Looney SW. Reliability of CAD CAM technology in assessing crown preparations in a preclinical dental school environment. J Dent Educ. 2014;78(1):40–50
2. Gratton DG, Kwon SR, Blanchette D, Aquilino SA. Impact of digital tooth preparation evaluation technology on preclinical dental Students' technical and self-evaluation skills. J Dent Educ. 2016; 80:91–9.
3. Murbay S, Neelakantan P, JWW C, Yeung S. Evaluation of the introduction of a dental virtual simulator on the performance of undergraduate dental students in the pre-clinical operative dentistry course. Eur J Dent Educ. 2019.

 doi:10.20944/preprints202410.1191.v1

4. Wolgin M, Grabowski S, Elhadad S, Frank W, Kielbassa AM. Comparison of a prepCheck-supported self-assessment concept with conventional faculty supervision in a pre-clinical simulation environment. Eur J Dent Educ. 2018; 22:e522–e9.
5. Gratton DG, Kwon SR, Blanchette DR, Aquilino SA. Performance of two different digital evaluation systems used for assessing pre-clinical dental students' prosthodontic technical skills. Eur J Dent Educ. 2017;21:252–60.
6. Cooper LF, Campbell SD. Digital technology: impact on and opportunities for dental education. In: Rekow D, editor. Digital dentistry. Surrey: Quinzessence Publishing; 2018. p. 251–67.
7. Welk A, Maggio MP, Simon JF, Scarbecz M, Harrison JA, Wicks RA, Gilpatrick RO. Computer-assisted learning and simulation lab with 40 DentSim units. Int J Comput Dent. 2008;11:17–40.
8. Schlenz MA, Michel K, Wegner K, Schmidt A, Rehmann P, Wöstmann B. Undergraduate dental students' perspective on the implementation of digital dentistry in the preclinical curriculum: a questionnaire survey. BMC Oral Health. 2020 ;20(1):78.
9. Flores-Mir C, Palmer NG, Northcott HC, Khurshed F, Major PW. Perception and attitudes of canadian dentists toward digital and electronic technologies. J Can Dent Assoc. 2006;72(3):243.
10. Sushmita V. Palanisamy, Chethan Hegde. Awareness Among Dental Undergraduate Students Regarding CAD/CAM Technology—A Survey Report, J Health Allied Sci NU 2019;9:57–63.
11. Maltar M, Miloš L, Milardović S, et al. Attitudes of the Students from the School of Dental Medicine in Zagreb towards CAD/CAM. Acta Stomatol Croat. 2018;52(4):322-329.
12. Rexhepi, I., Santilli, M., D'Addazio, G., Tafuri, G., Manciocchi, E., Caputi, S., & Sinjari, B. Clinical Applications and Mechanical Properties of CAD-CAM Materials in Restorative and Prosthetic Dentistry: A Systematic Review. Journal of functional biomaterials, 2023; 14(8), 431.
13. Suganna, M., Kausher, H., Tarek Ahmed, S., Sultan Alharbi, H., Faraj Alsubaie, B., Ds, A., Haleem, S., & Meer Rownaq Ali, A. B. Contemporary Evidence of CAD-CAM in Dentistry: A Systematic Review. Cureus, 2022; 14(11), e31687.
14. Davidowitz G, Kotick PG. The use of CAD/CAM in dentistry. Dent Clin North Am 2011;55(3):559–570.
15. Zitzmann NU, Matthisson L, Ohla H, Joda T. Digital Undergraduate Education in Dentistry: A Systematic Review. Int J Environ Res Public Health. 2020;17(9):3269.
16. Chatham C, Spencer MH, Wood DJ, Johnson A. The introduction of digital dental technology into BDS curricula. Br Dent J 2014;217(11):639–642.
17. Popa D, Burde A, Constantiniuc M, Ioana R, Bordea B, Compian RS. Students' attitude towards dental CAD/CAM systems: a questionnaire study. Am Sci Res J Eng Technol Sci 2015;14(3):250–254
18. Alghazzawi TF. Advancements in CAD/CAM technology: Options for practical implementation. J Prosthodont Res 2016;60:72-84.
19. Saponaro PC, Yilmaz B, Johnston W, Heshmati RH, McGlumphy EA. Evaluation of patient experience and satisfaction with CAD-CAM-fabricated complete dentures: a retrospective survey study. J Prosthet Dent 2016;116(4):524–528
20. Bhaskar H, Ganapathy D, Sivasamy V. Study of digital denture systems among dental students. Drug Invention Today. 2020 Mar 15;14(3).
21. Rekow ED. Digital dentistry: a comprehensive reference and preview of the future. 1st ed. Surrey: Quintessence Publishing Company Limited; 2018.
22. Beuer F, Schweiger J, Edelhoff D. Digital dentistry: an overview of recent developments for CAD/CAM generated restorations. Br Dent J. 2008;204:505–11.
23. Infante L, Yilmaz B, McGlumphy E, Finger I. Fabricating complete dentures with CAD/CAM technology. J Prosthet Dent 2014;111:351-5.
24. Ishida, Y., Kuwajima, Y., Kobayashi, T., Yonezawa, Y., Asack, D., Nagai, M., & Lee, S. J. Current implementation of digital dentistry for removable prosthodontics in US dental schools. Int J Dentistry 2022; 1; 7331185.